Georgia Tech Space Systems Design Laboratory
School of Aerospace Engineering

SOLAR POWER SATELLITE BUILDER CONCEPT

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Agenda

1. Solar Power Satellite
2. Modular Development
3. Small Satellite Design (Builder)
4. CONOPs
5. LEO Case Study

Modular Development of an SPS Using Small Satellites

WHAT:

- **Solar Powered Satellite (SPS): Large** Space Structures that orbit a celestial body and relay collected solar energy to a ground location via millimeter waves or microwaves.

WHY:

- Renewable energy source
- Transfer energy to any ground location
- Nearly limitless supply of energy source

HOW:

- **Built using:**
  - **Small satellites** will be sent up to space to **help construct and maintain** SPS through a **modular design method**
  - Satellites will **assemble semi-autonomously**

Turner et. al, Solar Power Satellite Builder Concept, Space Generation Congress, Dubai, UAE, 2021

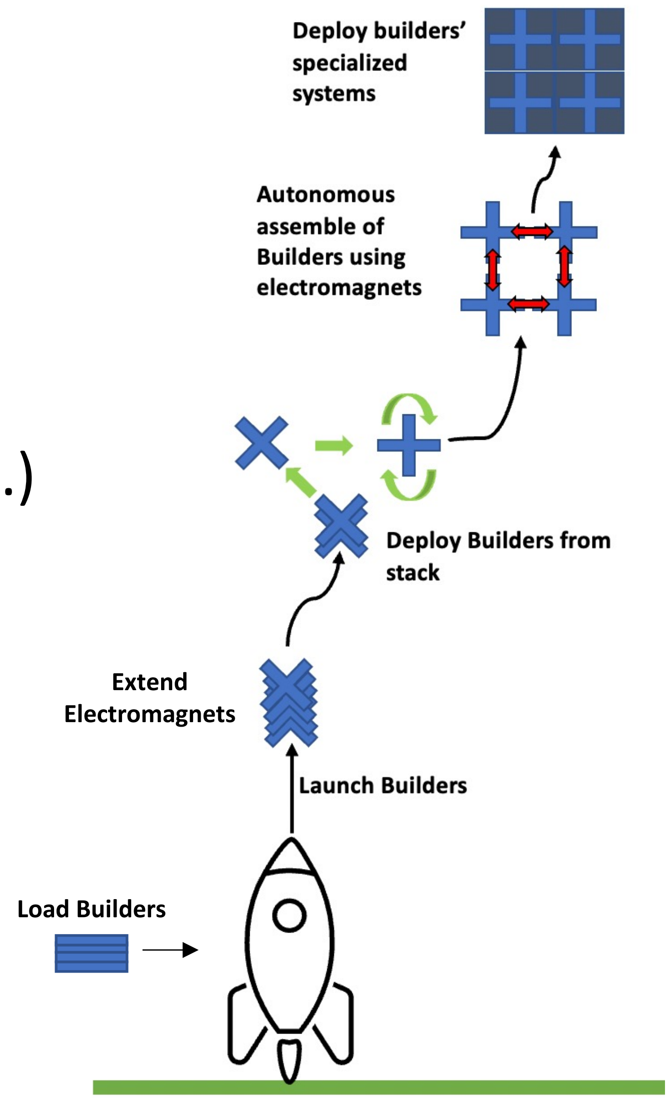
Assembly Method

<u>Free-flyer approach</u>

- Each builder satellite is an independent operating spacecraft

- **Requirements:**
- Builder need flight critical systems (propulsion, power, ACS, etc.)
- Specific degree of intelligence

- **Benefits:**
- Allows integrated modular assembly using **ridesharing**
- Spreads costs of an SPS system over time
- Allows SPS systems to manipulate design



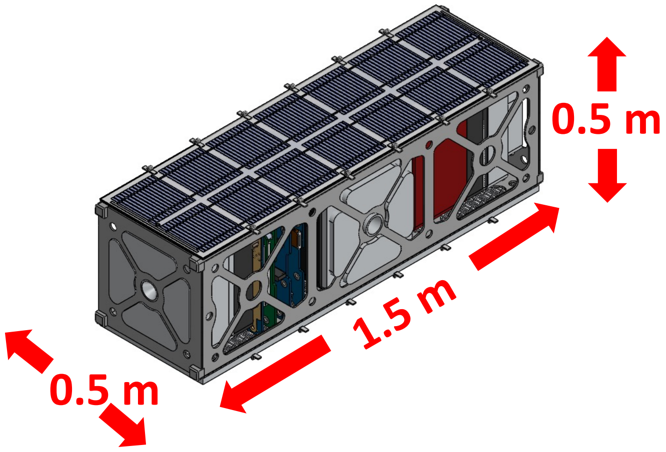
Semi-autonomous Assembly Method

Turner et. al, Solar Power Satellite Builder Concept, Space Generation Congress, Dubai, UAE, 2021

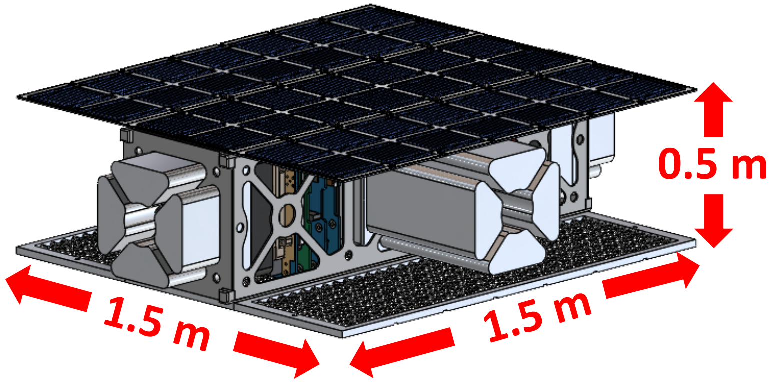
Builder Concept

- **Mass*:** Approx. 200kg
- **Launch Size:** 1.5 X 0.5 X 0.5 meter
- **Fully Deployed Size:** 1.5 X 1.5 X 0.5 meter
- 4 Electromagnets
- **Simple base system architecture**
- **Interchangeable specialized system architecture**
  - Extendable Mirrors
  - Solar Panels
  - RF Receiver/Transmitter
- **Cost*:** Approx. $250,000

*Will vary with types of power storage devices/specialized systems



Builder Satellite ready for Launch



Builder Satellite with Electromagnets and Specialized Systems Deployed

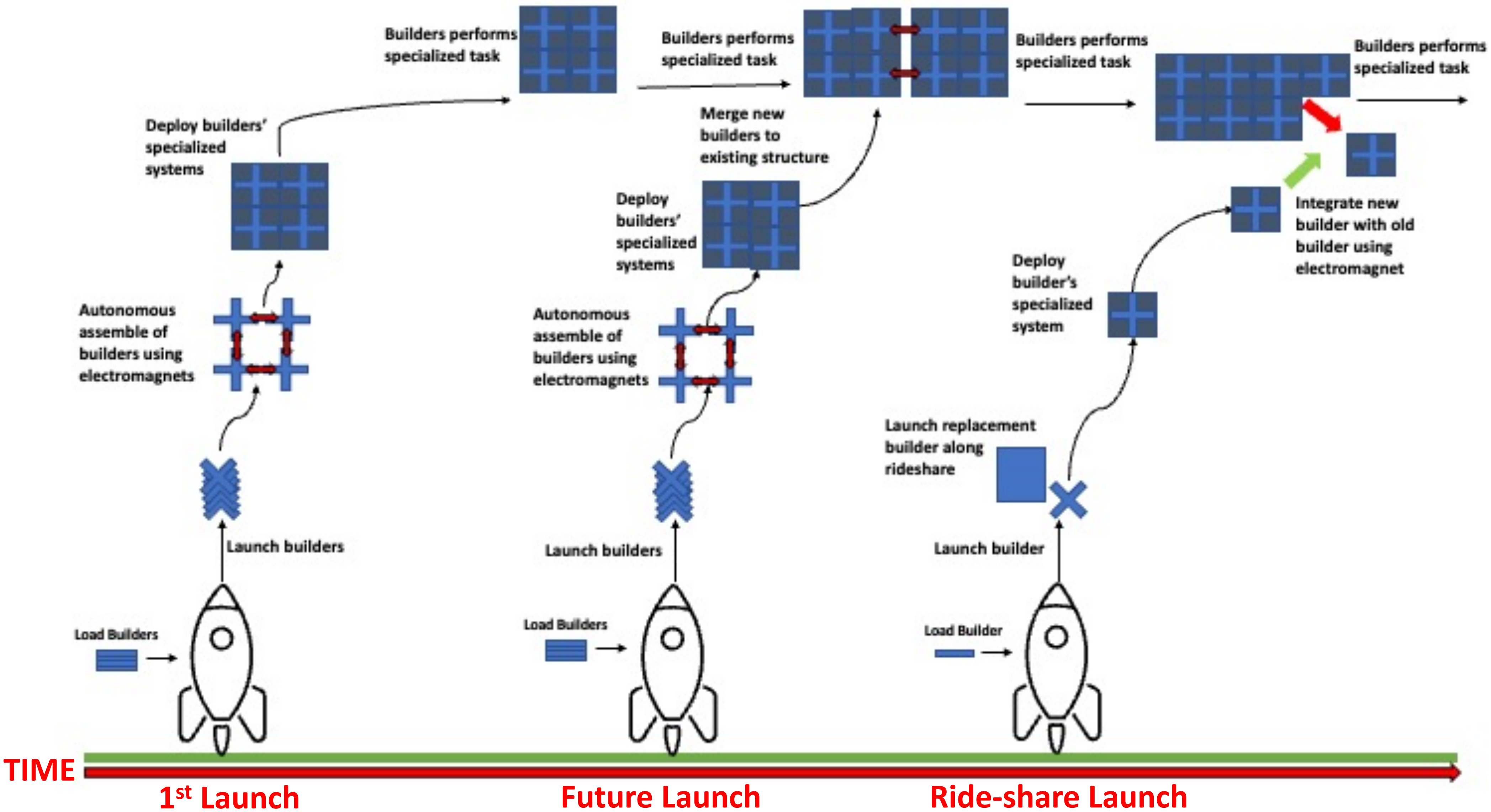
Turner et. al, Solar Power Satellite Builder Concept, Space Generation Congress, Dubai, UAE, 2021

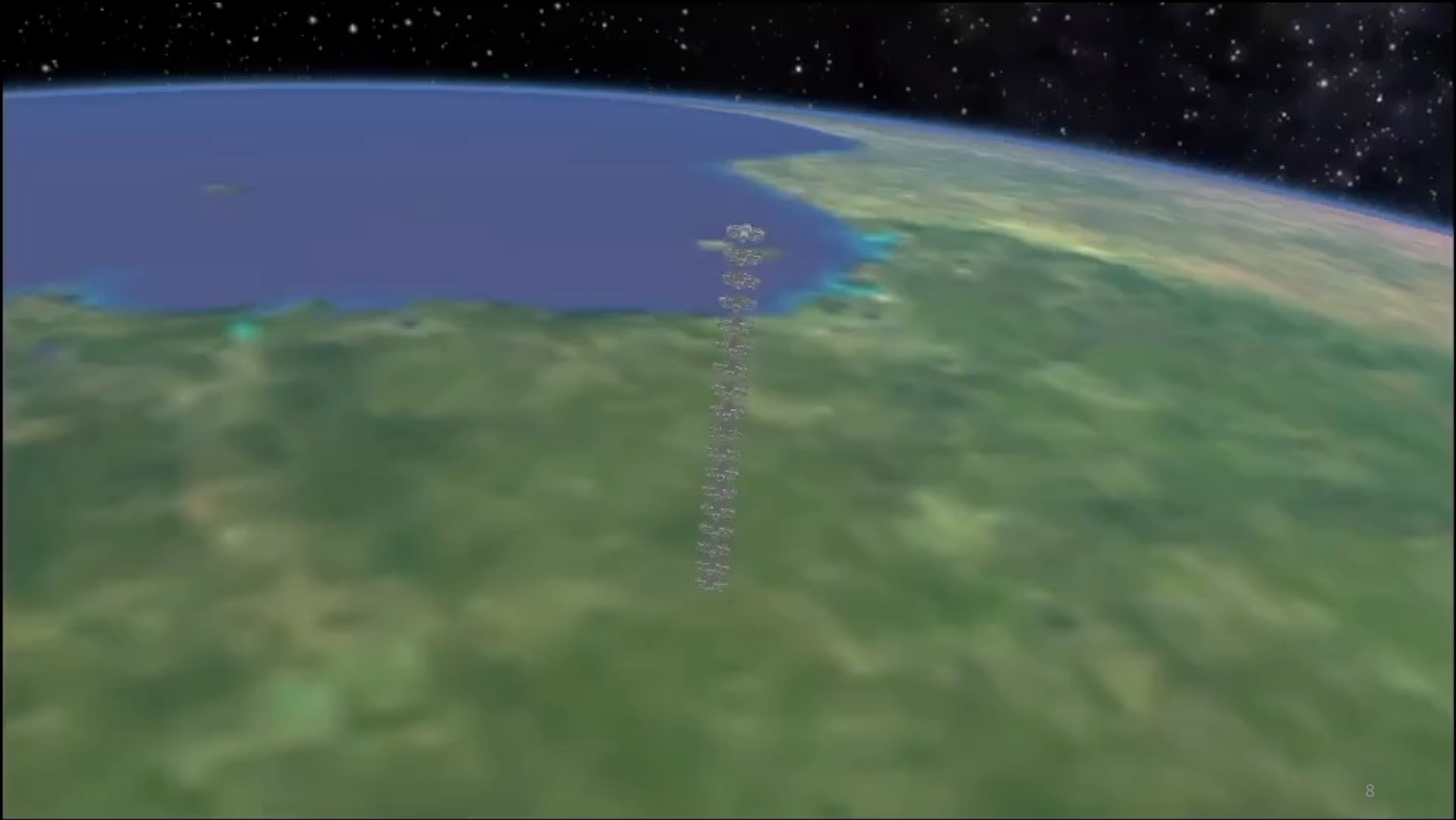
Key System: Electromagnet Capabilities

- A **reduction** could be made in the dependency for **precision sensors and thrusters** commonly used in spacecraft maneuvers such as docking
- Ability to **attract and repel** spacecraft to another spacecraft becomes as simple as **varying the electromagnetic field**
- Containing **minimal mechanical mechanisms** and having the ability to be **inexpensive**, **lightweight**, and **easy to manufacture**
- Inductive coupling capabilities to allow for **wireless energy transfer**

Turner et. al, Solar Power Satellite Builder Concept, Space Generation Congress, Dubai, UAE, 2021

Concept of Operations





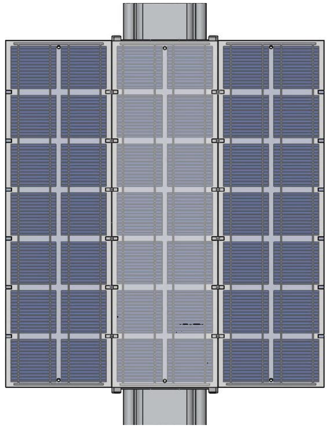
LEO Case Study

Scale

- **One SPS Station:** Approx. 1000 m^2
- **Number of Builder Satellites to build 1 SPS station**: Approx. 450

Why

- The **size of the SPS** to be built can be **reduced** since the transmission losses of sending energy to a target location are lower at smaller distances
- More satellites can be **delivered to LEO** on a **shorter timeline** and at a **lower cost** than MEO and HEO
- **Rideshare** opportunities are widely **available at LEO** allowing ease of replacement and integration of new satellites.



Builder satellite with solar panels and RF transmitter

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Launch Phase

Initial Setup for 1000 m^2 SPS station

Altitude: Approx. 1500 km

Falcon 9 rocket

- **Number of Launches:** 4
- Approx. **115** satellites per launch
- **CO_2 Footprint per Launch*:** 400 Metric Tons CO_2
- **Cost per Launch*:** $62,000,000
- **Total CO_2 Footprint:** 1600 Metric Tons CO_2
- **Total Cost per SPS material:** $115,000,000

Total Cost for Building SPS: Approx. $363,000,000

Builder Satellites in launch configuration

*Using 2021 data, values are expected to decrease over time

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Energy & CO2 Calculations

Solar Cell

Silicon:

- **Total energy transfer efficiency:** 8%
- **Total Power Received:** Approx. 100 KWh
- **Total CO_2 Offset:** 40 kg/h

Gallium Arsenide:

- **Total energy transfer efficiency:** 16%
- **Total Power Received:** Approx. 220 KWh
- **Total CO_2 Offset:** 90 kg/h

Solar Constant: 1380 watt/m^2

Amount of CO_2 per KWh: 0.417 kg/KWh

Factors Affecting Power Collection	Efficiency
Error of Sun-Pointing	0.99
Gap of Solar Cells	0.85
Angle of Sunlight	0.958
Space Environment Effect	0.90
Voltage Conversion in Antenna	0.95
Consumed by Service Devices	0.999
Microwave Generator	0.85
Microwave Regulation	0.98
Microwave Transmission	0.90
Receiving Antenna	0.90
Rectifier Circuits	0.85

Factors affecting power collection on ground site

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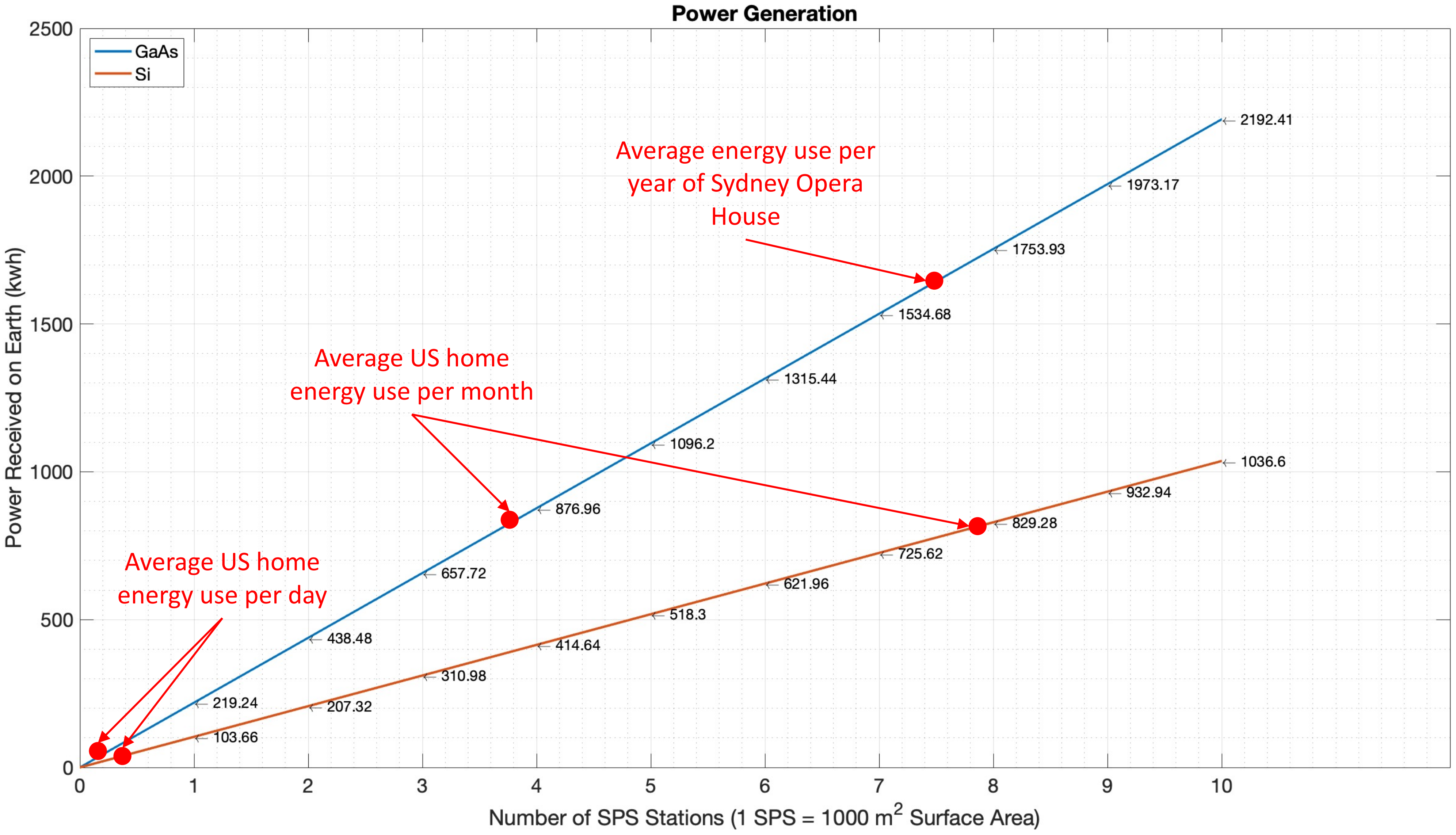
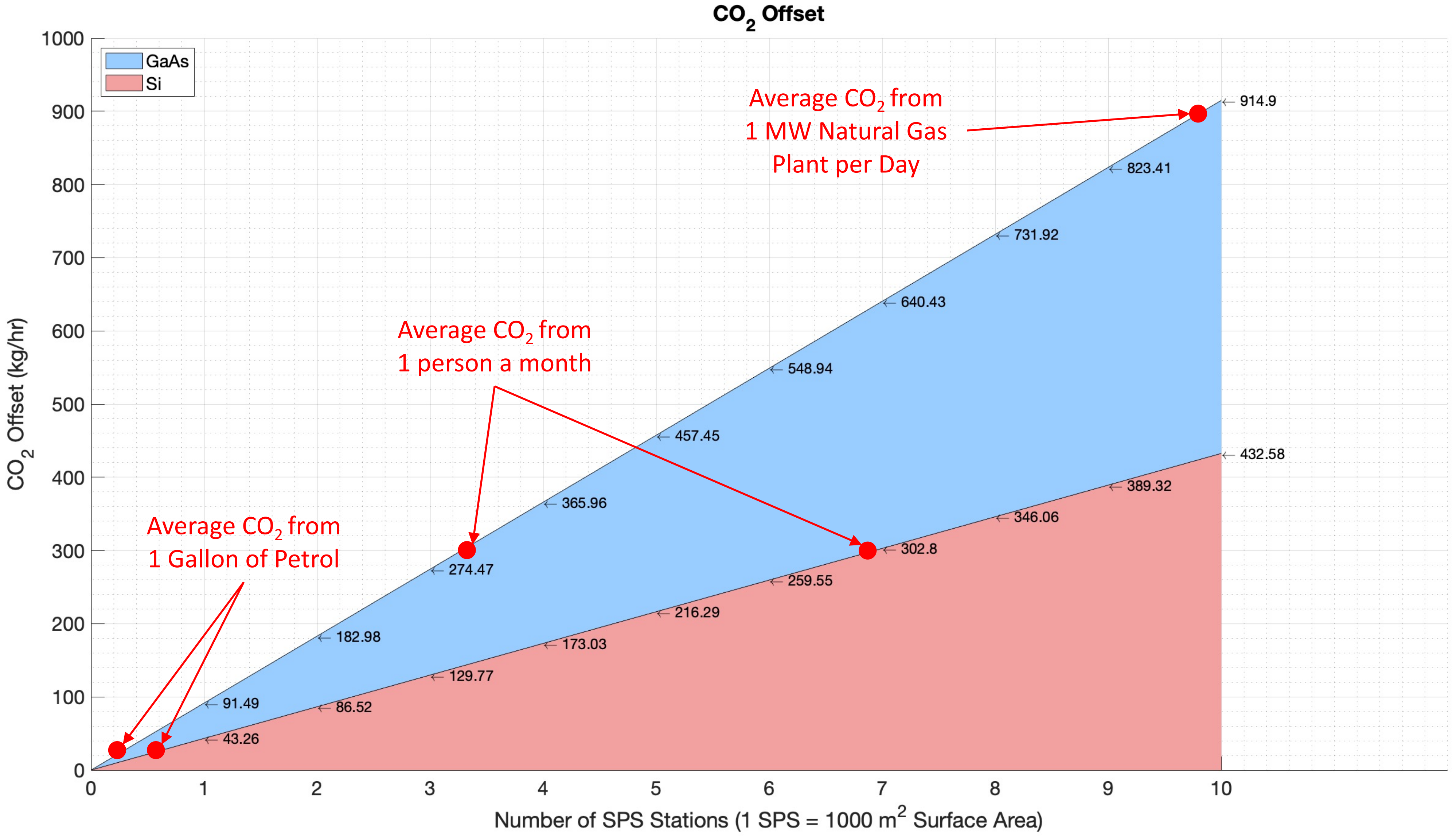
Energy Generation from SPS



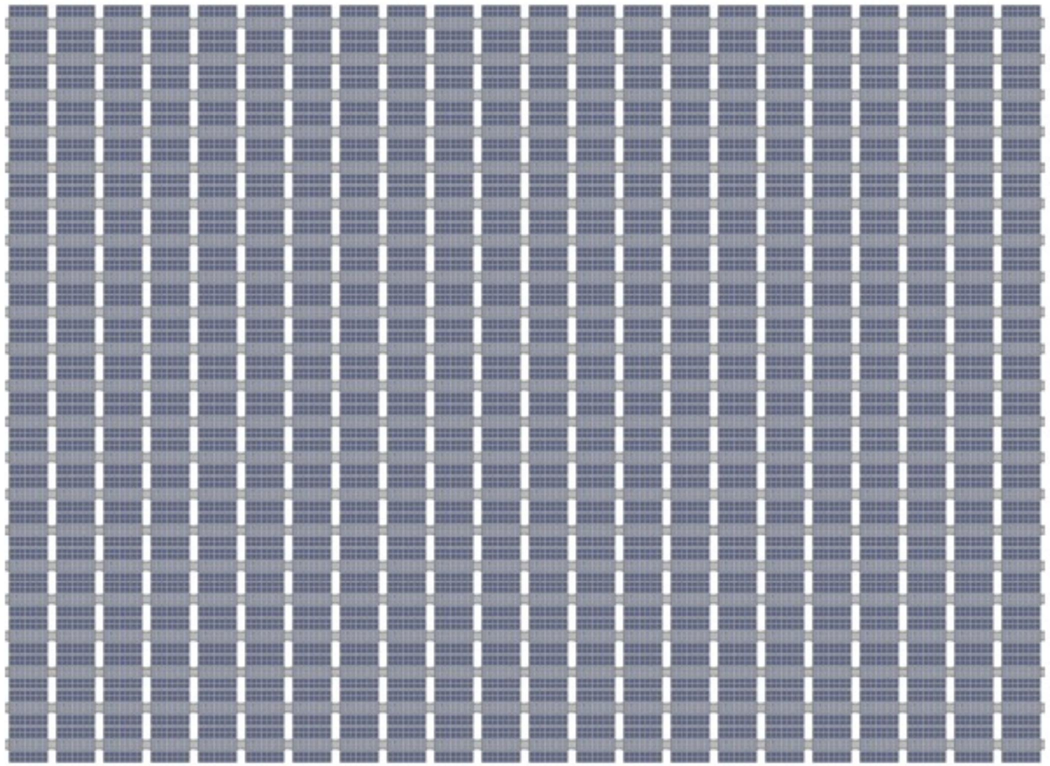
CO2 Offset from Developing SPS



Conclusion

One 1000 m^2 SPS station

- **Total Cost:** Approx. $363,000,000
- **Power Generation***
  - **Silicon solar cells:** Approx. 100 kwh
  - **Gallium Arsenide solar cells:** Approx. 220 kwh
- **CO_2 Offset**
  - **Silicon solar cells:** Approx. 40 kgs/hr
  - **Gallium Arsenide solar cells:** Approx. 90 kgs/hr
- **Years to offset CO_2 footprint**
  - **Silicon solar cells:** Approx. 9 years
  - **Gallium Arsenide solar cells:** 4 years



1000 m^2 Solar Power Satellite system

*Assumes solar panel is in total sunlight total

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Moving Forward

<u>LEO SPS</u>

- Looking at optimal orbit trajectories to use LEO SPS
- Looking at how many LEO SPS are needed to provide constant energy

<u>Spacecraft design for modular development</u>

- Research spacecraft assembling and disassembling using electromagnets
- Research the use of electromagnets transferring energy in space
- Optimize builder satellites mass to surface area ratio

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Thank You